# Optimal Timing of Preventive Maintenance Kickoff Meeting

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# Introduction

- Current guidelines for applying maintenance treatments based on observations of pavement surface condition
- Significant resources can be saved if reactive maintenance activities are replaced by **<u>proactive</u>** activities
- This approach requires
  - Better understanding of the fundamental mechanisms that control the deterioration process
    - ✓Role played by "aging"
  - Better detection methods of the inception of deterioration, in particular at the surface
    - ✓Formation of micro cracks

# Introduction

- "Aging" in asphalt binders is generally accepted to be the cause of hardening of the asphalt over time
- The primary mechanisms of age hardening were determined to be
  - Oxidation
  - Loss of volatiles
  - Steric hardening
- These mechanisms are very complex
  - **The evolution with time and relationship to mechanical properties not well understood**

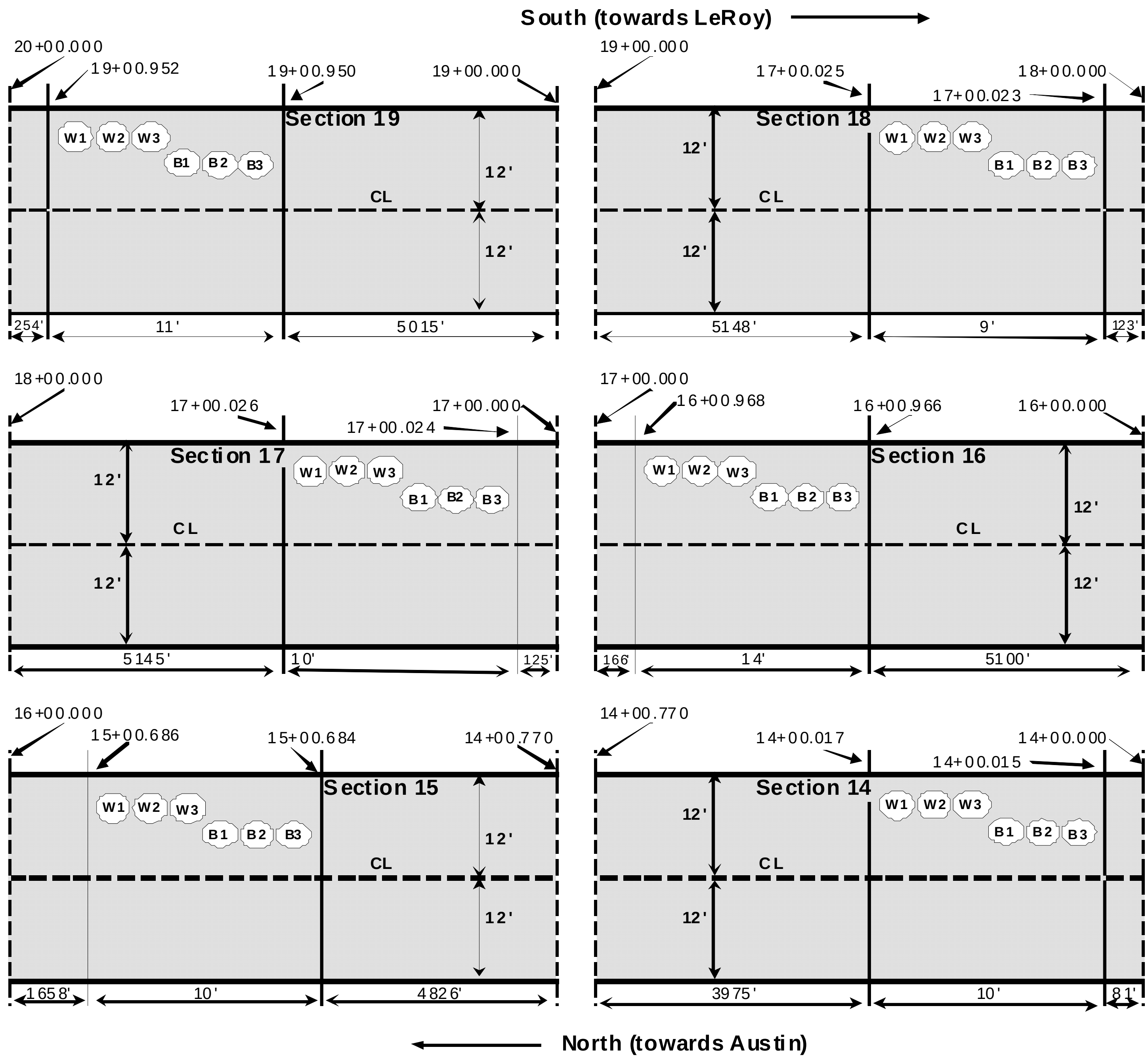
# Introduction

- Recent study at the U focused on finding an optimum application time for surface treatments
  - Use field mixture and binder samples to
    - ✓Detect and quantify “aging” products
    - ✓Measure mechanical properties to quantify effect of “aging” on these properties
  - Investigate methods to detect presence of micro-cracks on pavement surface
  - Extensive investigation of temperature variation in pavements exposed to real environmental conditions using MnROAD extensive data base

# Surface Treatment Timing - TH 56

| Section No. | Seal coat application year | Pavement construction year | Age when treated | Agg. Type | Emulsion rate (gal/yd$^2$) | Agg. rate (lb/yd$^2$) | Fog Seal rate (gal/yd$^2$) |
|---|---|---|---|---|---|---|---|
| 10 | Control | 1999 | N/A | N/A | - | - | - |
| 14 | 2000 | 1999 | 1 | NUQ | 0.32 | 16 | 0.11 |
| 15 | | 1995 | 5 | NUQ | | | |
| 13 | 2001 | 1999 | 2 | DTR | 0.34 | 17-18 | 0.11 |
| 16 | | 1995 | 6 | DTR | | | |
| 12 | 2002 | 1999 | 3 | DTR | 0.38-0.42 | 18-22 | 0.11 |
| 17 | | 1995 | 7 | DTR | 0.40-0.44 | 18 | 0.11 |
| 11 | 2003 | 1999 | 4 | DTR | 0.4 | 19 | 0.13 |
| 18 | | 1995 | 8 | DTR | 0.44 | 19.5 | 0.13 |
| 19 | Control | 1995 | N/A | N/A | - | - | - |

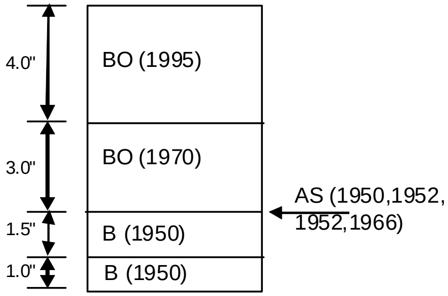
# TH 56


South (towards LeRoy)
20+00.000
19+00.952
19+00.950
19+00.000
Section 19
W1 W2 W3
B1 B2 B3
12'
CL
12'
2.54'
11'
50.15'
19+00.000
17+00.025
18+00.000
17+00.023
Section 18
12'
CL
12'
51.48'
9'
1.23'
18+00.000
17+00.026
17+00.000
17+00.024
Section 17
12'
CL
12'
51.45'
10'
1.25'
17+00.000
16+00.968
16+00.966
16+00.000
Section 16
12'
CL
12'
1.66'
14'
51.00'
16+00.000
15+00.686
15+00.684
14+00.770
Section 15
12'
CL
12'
16.58'
10'
48.26'
14+00.770
14+00.017
14+00.000
14+00.015
Section 14
12'
CL
12'
39.75'
10'
8.1'
North (towards Austin)

# TH 56

| Specimen ID | Work Item | Material ID | Date | Depth(in) | Width(ft) | Mode |
|---|---|---|---|---|---|---|
| 56-16-95-B-3 | Bituminous Overlay | 41 | 7/1/1995 | 4 | 24 | In place |
| 56-16-95-W-3 | Mill Bituminous | | 7/1/1995 | -1.5 | 24 | In place |
| 56-17-95-B-3 | Spot Overlay | 31 | 6/4/1980 | 1 | NA | In place |
| 56-17-95-W-3 | Bituminous Overlay | 31 | 10/6/1970 | 1.5 | 25 | In place |
| | Bituminous Overlay | 41 | 10/6/1970 | 3 | 24 | In place |
| | Agg. Seal Coat | F1 | 6/29/1966 | NA | NA | In place |
| | Spot Overlay | ** | 9/17/1959 | 1 | NA | In place |
| | Spot Overlay | ** | 8/18/1955 | 1 | NA | In place |
| | Agg. Seal Coat | ** | 9/29/1952 | NA | NA | In place |
| | Agg. Seal Coat | ** | 9/29/1952 | NA | NA | In place |
| | Agg. Seal Coat | ** | 7/29/1950 | NA | NA | In place |
| | Bituminous Layer | 31 | 7/29/1950 | 1.5 | 24 | New |
| | Bituminous Layer | 31 | 7/29/1950 | 1 | 26 | New |
| | Agg. Base Layer | ** | 7/29/1950 | 1.5 | 42 | New |







# Surface Treatment Type - TH 251

| Treatment | Specimen ID | Thickness (in) | Offset from Centerline | Location |
|---|---|---|---|---|
| Control | 251-2-B-1 | 6 1/4 | 6'-6" | RP 9+00.123 |
| | 251-2-B-2 | 6 1/4 | 6'-6" | RP 9+00.123 |
| | 251-2-B-3 | 6 1/4 | 6'-6" | RP 9+00.123 |
| | 251-2-W-1 | 6 1/2 | 9'-0" | RP 9+00.124 |
| | 251-2-W-2 | 6 1/2 | 9'-0" | RP 9+00.124 |
| | 251-2-W-3 | 6 1/2 | 9'-0" | RP 9+00.125 |
| CSS-1h 2002 | 251-3-B-1 | 6 | 4'-0" | RP 9+00.304 |
| | 251-3-B-2 | 6 | 4'-0" | RP 9+00.305 |
| | 251-3-B-3 | 5 3/4 | 4'-0" | RP 9+00.305 |
| | 251-3-W-1 | 5 3/4 | 8'-0" | RP 9+00.303 |
| | 251-3-W-2 | 5 3/4 | 8'-0" | RP 9+00.303 |
| | 251-3-W-3 | 6 | 8'-0" | RP 9+00.304 |
| Reclamite 2002 | 251-6-B-1 | 4 7/8 | 5'-6" | RP 9+00.578 |
| | 251-6-B-2 | 4 7/8 | 5'-6" | RP 9+00.578 |
| | 251-6-B-3 | 4 7/8 | 5'-6" | RP 9+00.578 |
| | 251-6-W-1 | 5 | 7'-6" | RP 9+00.579 |
| | 251-6-W-2 | 5 | 7'-6" | RP 9+00.579 |
| | 251-6-W-3 | 5 | 7'-6" | RP 9+00.580 |
| Chip Seal 2002 | 251-8-B-1 | 5 3/8 | 5'-6" | RP 9+00.810 |
| | 251-8-B-2 | 5 3/8 | 5'-6" | RP 9+00.810 |
| | 251-8-B-3 | 5 3/8 | 5'-6" | RP 9+00.810 |
| | 251-8-W-1 | 5 1/8 | 8'-6" | RP 9+00.811 |
| | 251-8-W-2 | 5 1/8 | 8'-6" | RP 9+00.811 |
| | 251-8-W-3 | 5 1/4 | 8'-6" | RP 9+00.812 |

# Detecting Aging Products

- Detection of oxidation products (ketones, etc) by means of a simple experiment is of significant importance
- FTIR spectral analysis has been performed on samples of asphalt binder extracted from field mixtures.
  - Concerns related to the use of chemical solvents in the extraction process
- Can it be done directly on mixtures?
  - Research in progress at Western Research Institute
    - ✓NMR and FTIR-ATR methods
  - Worked performed in Australia (Norrison, E&E 2004)
    - ✓X-Ray Photoelectron Spectroscopy (XPS)

# X-Ray Photoelectron Spectroscopy

- The limited results obtained in this study indicated that XPS test is capable of detecting the presence of oxidized carbon functional groups
  - However, very little C=O functional groups were detected
  - Furthermore, the amounts of ketones varied significantly between the replicates of the same sample, indicating poor repeatability of the test
- Therefore, this procedure may not be very useful for routine investigation of aging in asphalt pavements

# Fourier Transform Infrared Spectroscopy

- Mature technique
  - One of the most widespread methods used to identify and quantify amounts of known and unknown materials
- Currently used to detect aging products in asphalt binders (e.g. carbonyl peak)
  - Requires chemical extraction of binders
- Analysis of the spectra needs to be carefully done
  - Need the spectra of the original binders to quantify aging
  - Not always possible unless long range research

# Fourier Transform Infrared Spectroscopy

- Research in Minnesota focused on quantifying "aging" variation with layer depth
  - Samples extracted from pavement cores
  - Thin slices, with a thickness of approximately 5 mm each, cut from the cores
    - ✓Sample A represents the first slice (top of the core)
- Results indicate most aging occurs in the top 5mm
  - Sacrificial layer?
    - ✓Replace or "rejuvenate" periodically?

| 03/28 Layer | Calculated Area | Normalized Area |
|---|---|---|
| Unaged | -0.16 | 0.00 |
| A | 0.32 | 0.48 |
| B | 0.06 | 0.22 |
| C | -0.05 | 0.11 |
| D | 0.06 | 0.22 |
| E | -0.06 | 0.10 |
| F | -0.05 | 0.11 |
| G | -0.10 | 0.06 |
| H | -0.04 | 0.12 |
| I | -0.13 | 0.03 |
| J | -0.03 | 0.13 |
| K | -0.06 | 0.10 |
| L | -0.08 | 0.08 |
| M | -0.12 | 0.04 |
| N | -0.06 | 0.10 |
| O | -0.02 | 0.14 |
| P | -0.04 | 0.12 |
| Q | -0.03 | 0.13 |
| R | -0.04 | 0.12 |
| S | -0.02 | 0.14 |
| T | 0.06 | 0.22 |
| U | | |
| V | | |
| W | | |
| X | | |
| Y | | |
| Z | | |

Sample Prep: Extraction with THF and then evaporated to dryness (ran as solid).

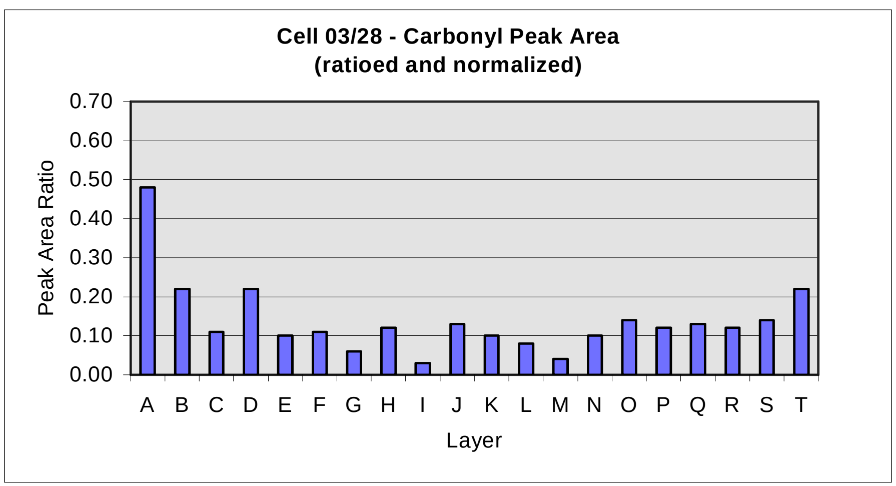
Intrument: Thermo Nicolet Nexus 470

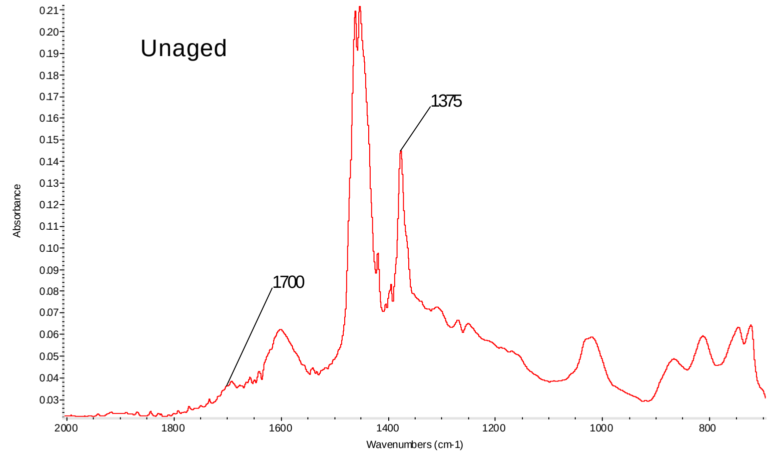
Atmosphere: Ambient with automatic H2O and CO2 suppression

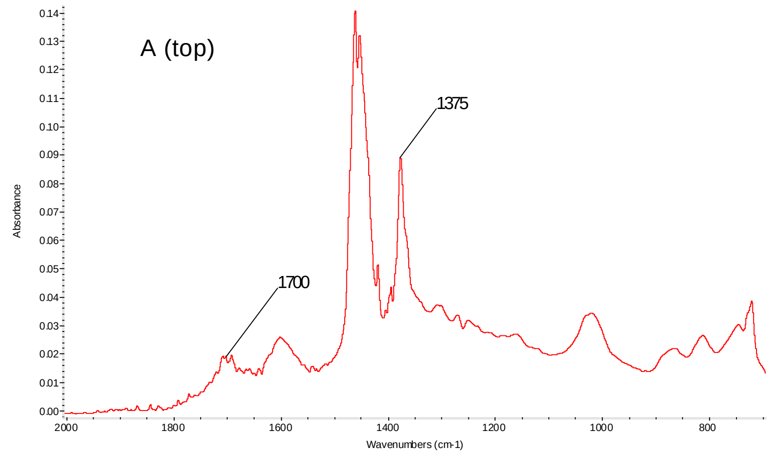
Test Fixture: ATR with ZnSe crystal

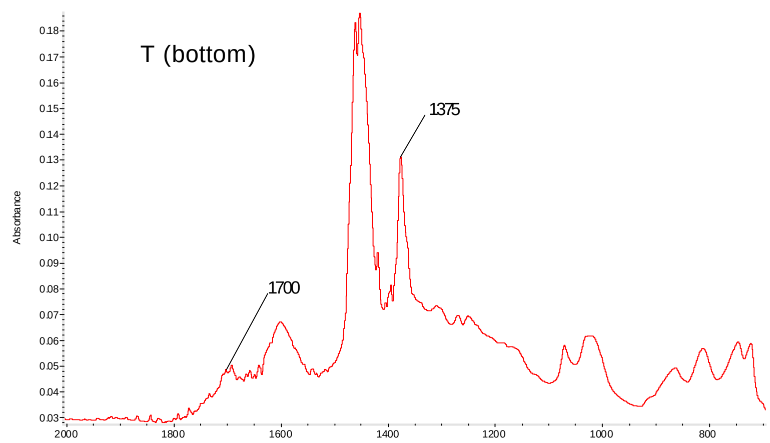
Area Calculation: Ratio of peak area at 1700 cm-1 to the peak area at 1375 cm-1 using TQ Analyst software package.

Cell and Binder: 03/28, 120/150



# Mechanical Properties

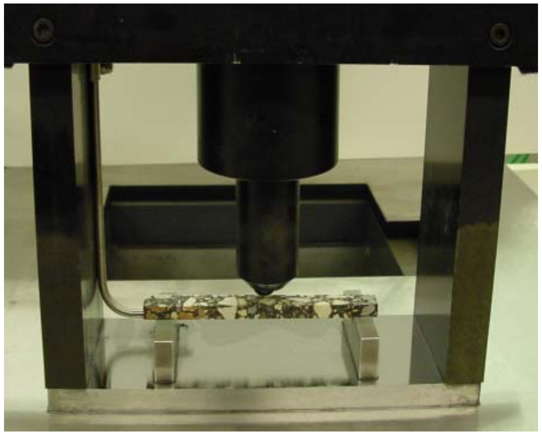
- Goal: identify change in properties with pavement age
  - DSR, BBR, DT tests on **asphalt binder extracted** from cores
    - ✓Very limited quantities
    - ✓Chemical extraction may affect properties
  - SCB, IDT tests on **mixture specimens** cut from cores taken from pavements
    - ✓Test specimens very large (2" to 6" for E*)
      - Cannot identify aging effect with pavement depth

# BBR on Mixture Beams

- Used method proposed by U research team in 2005
  - Evaluate change in mixture properties with asphalt layer depth
    - ✓ Aging effects
    - ✓ Other effects (compaction, lift, etc)
  - Can also be used to back calculate binder properties
    - ✓ Important for determining allowable limits for adding RAP

# BBR on Mixture Beams

- Creep test performed at low temperatures using the same equipment used to grade asphalt binders
    - Bending Beam Rheometer
- Comparison with results from IDT very encouraging
- *Work in progress to understand why it works*
    - *Representative Volume Element at low temperature*



# Micro Cracks Detection

- Most maintenance actions triggered from <u>visual</u> observations of the pavement surface
  - Can distresses (cracks) be detected in the initial stage of formation and propagation?
    - ✓Significant savings using proactive approach
- Potential methods to detect micro cracks on the pavement surface were investigated
  - Two specific features of asphalt pavements make micro cracks detection very difficult
    - ✓Pavement surface texture
    - ✓Ability of asphalt pavements to "heal"
      - Best time to detect micro cracks: late fall and winter?

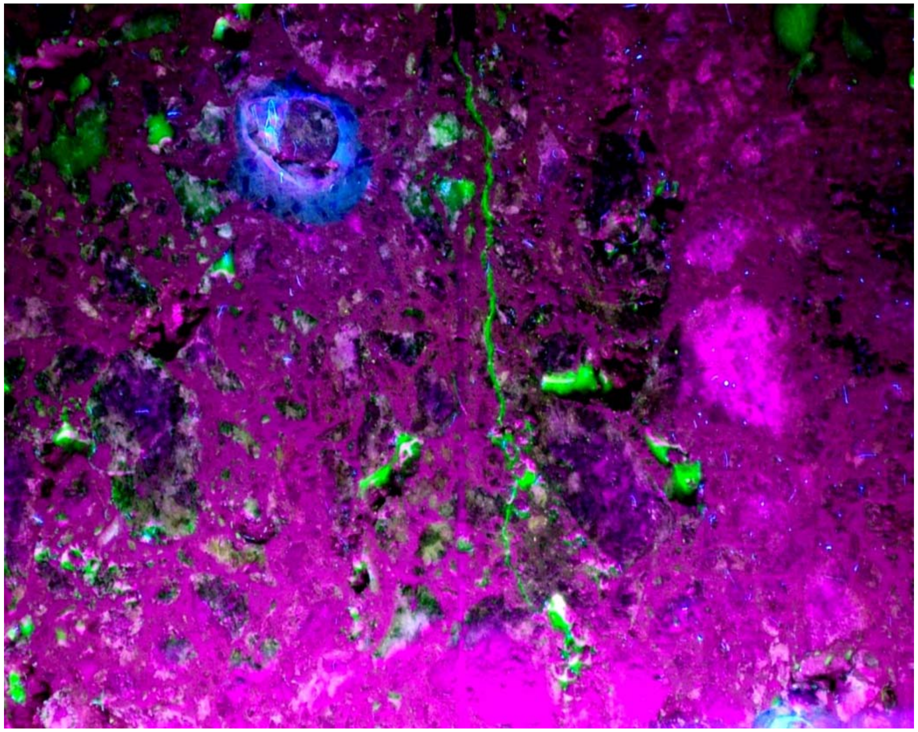
# Electron Microprobe

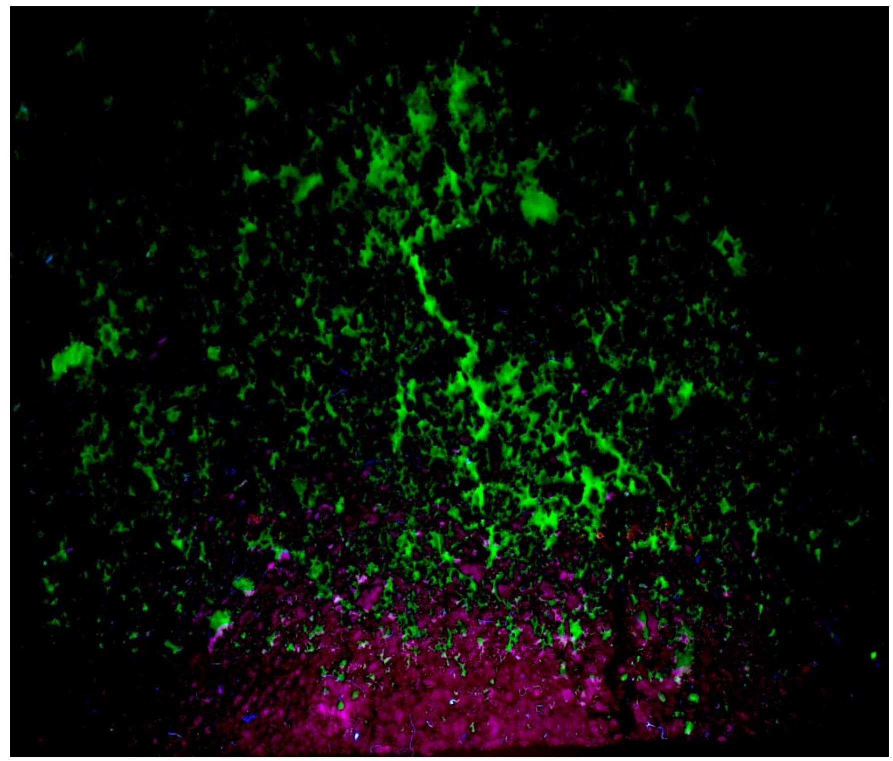
- Specimen preparation expensive and time consuming
- Specimen tested might not be representative of what is observed in the field
  - Localized nature of the test
- Only cracks on the surface of the aggregates detected
  - Crushing process or field compaction?
    - ✓ Crack initiators at low and intermediate temperatures – can aggregate crushing be avoided?
  - Mastic healing at room temperature?
    - ✓ Special storage of test specimen at low temperature

# Fluorescent Penetrant

- Need simpler method that provides global evaluation of the pavement surface
- One potential method: fluorescent dyes to detect micro cracks
  - Used in several industries: aerospace, automotive, welding, pipelines, steel mills
  - Recent studies on dental ceramic materials indicated that microscopic cracks of critical sizes could be detected using the fluorescent penetrant method, which were not detectable by light-optical microscopy and SEM.

# Fluorescent Penetrant





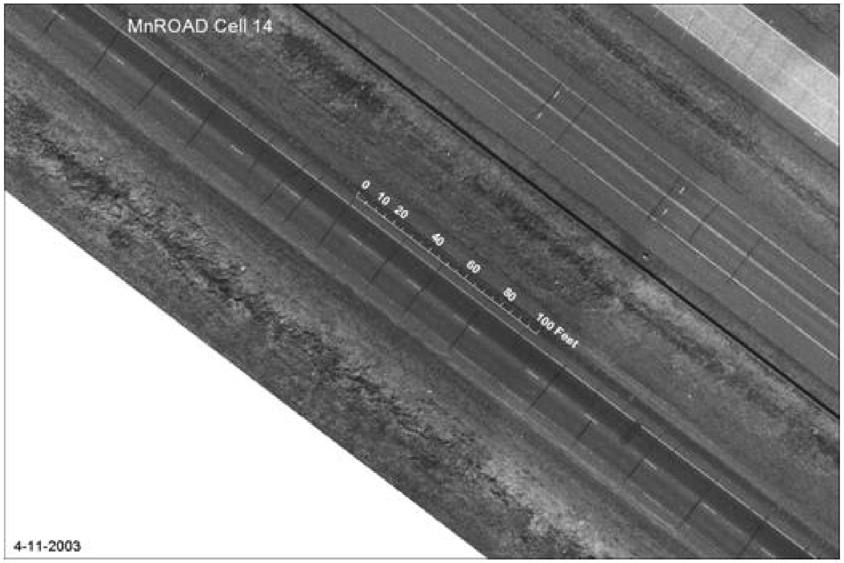
# Fluorescent Penetrant

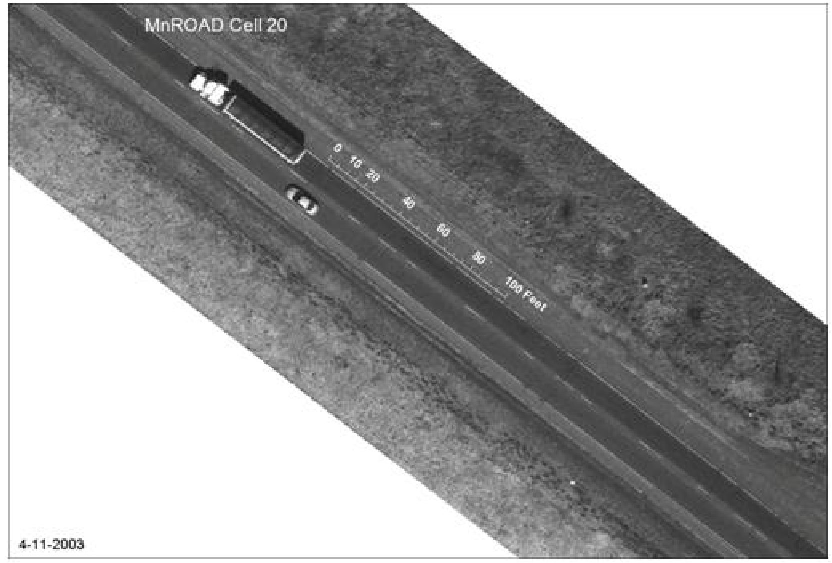
- Further work needed considering the following ideas
  - Mix penetrant with a surfactant to enhance its ability to penetrate microcracks
    - ✓ Add 1% dish washing soap
    - ✓ Use 1% non-ionic surfactant solution of ethylene oxide with low critical micelle concentration
  - Use powerful UV lamp and develop better surface preparation and cleaning techniques
  - Perform field tests (MnROAD) at night time
    - ✓ Measurements on the exact same area at different temperature regimes (summer vs. winter)

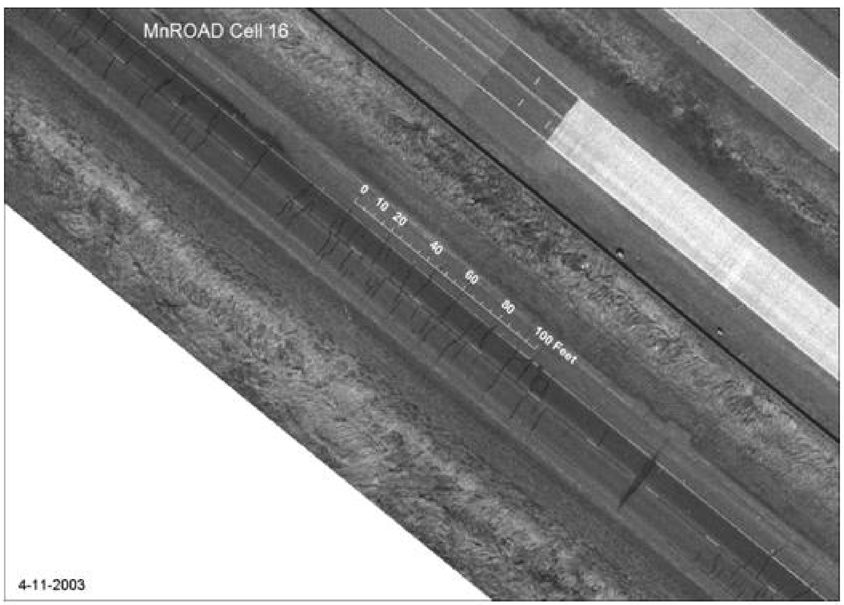
# Remote Sensing

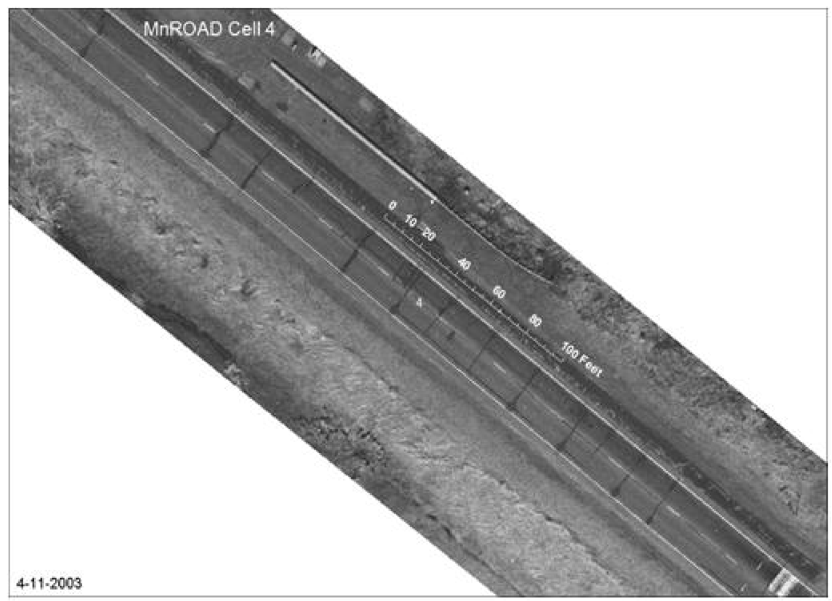
- Over the past years attempts to evaluate pavement condition at MnROAD using remote sensing
  - High resolution aerial pictures taken from aircraft flying at low altitude
    - ✓Low temperature cracking patterns
    - ✓Very expensive
    - ✓Most of the information can be obtained from instrumented vans
    - ✓Recently abandoned
- Satellite images
  - Resolution too low for commercial satellites

# Aerial Photography

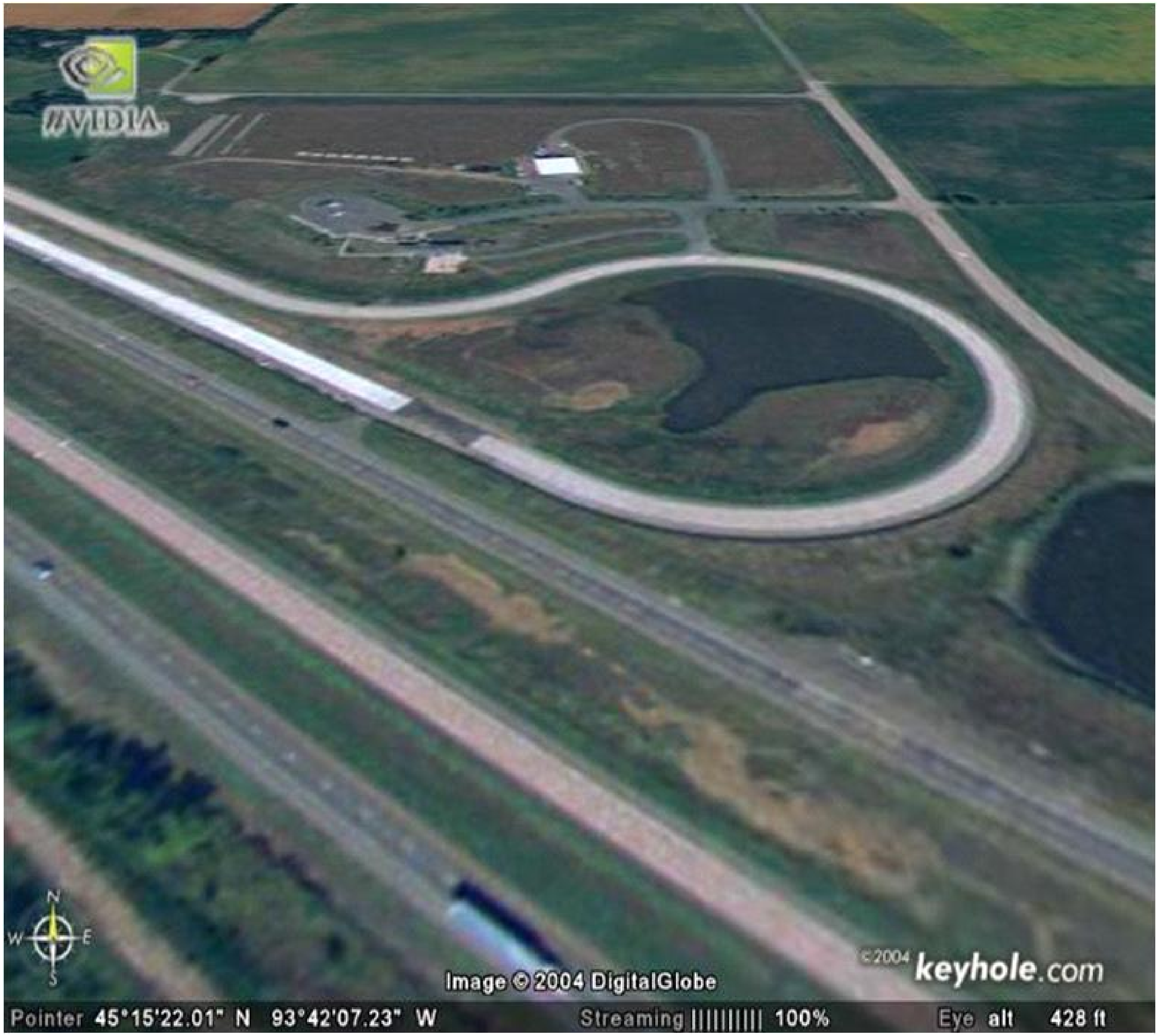


# Satellite Images




Images now available on Google Earth

# Remote Sensing in Transportation

- The U.S. Department of Transportation (USDOT) and the Research and Special Programs Administration (RSPA) established The National Consortia on Remote Sensing in Transportation (NCRST) in 2000
- Four university-led consortia were set up
  - Environment
  - Infrastructure - led by University of California Santa Barbara ( http://www.ncgia.ucsb.edu/ncrst/ )
  - Traffic Flows
  - Hazards

# Spectral Analysis of Asphalt Pavement Surface

- In past years, advanced detection systems used primarily in atmospheric and environmental applications have been used as potential investigative tools in transportation
  - Studies performed by UCSB researchers have shown that the principles of imaging spectrometry can be used to estimate the physical structure and chemical composition of the surface of asphalt pavements
  - It may become possible to use spectral characteristics of asphalt pavements to provide useful information regarding aging and deterioration of the road

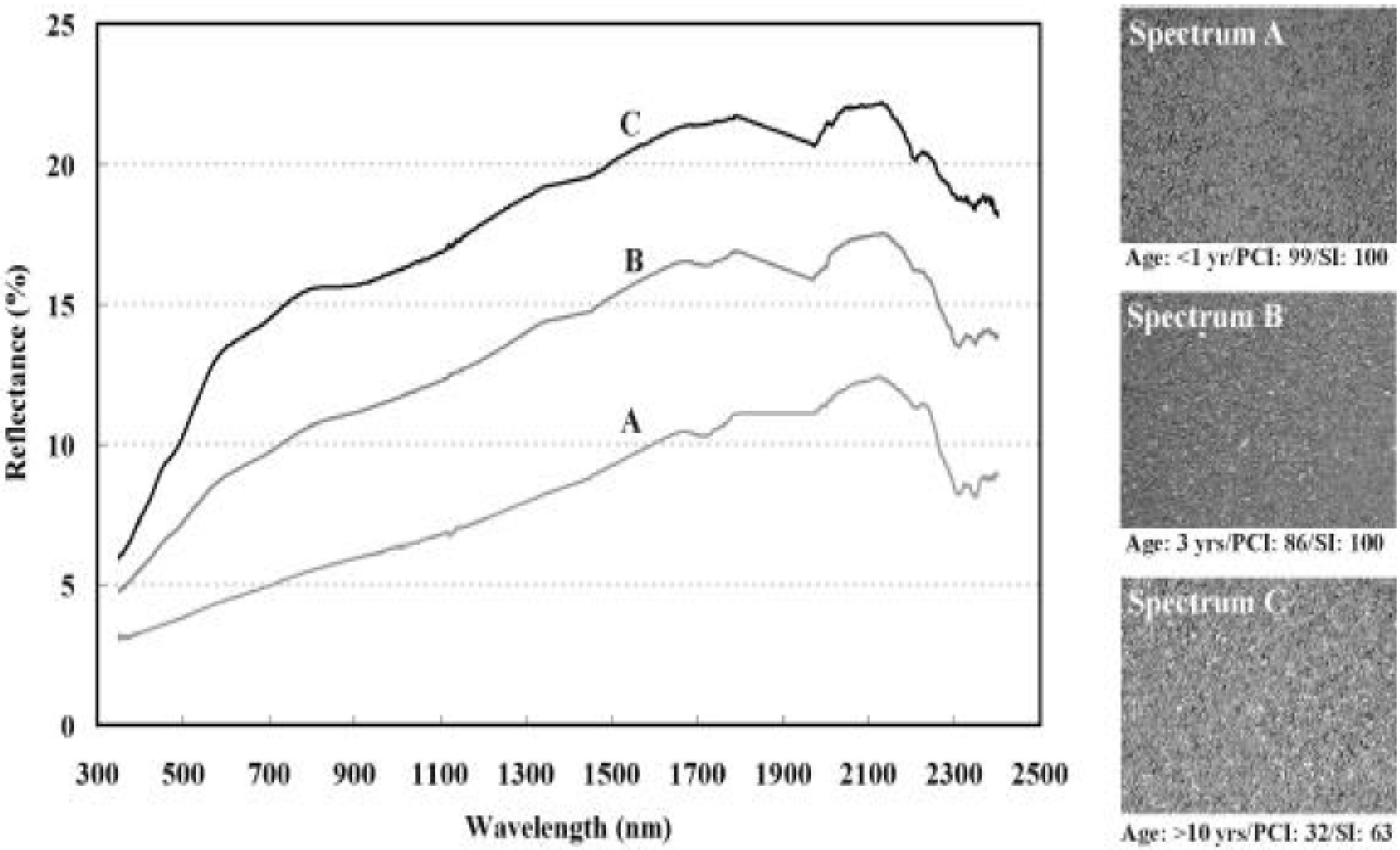



Figure 1: Spectral effects of asphalt aging and deterioration from the ASD ground spectral measurements (the major water vapor absorption bands are interpolated).

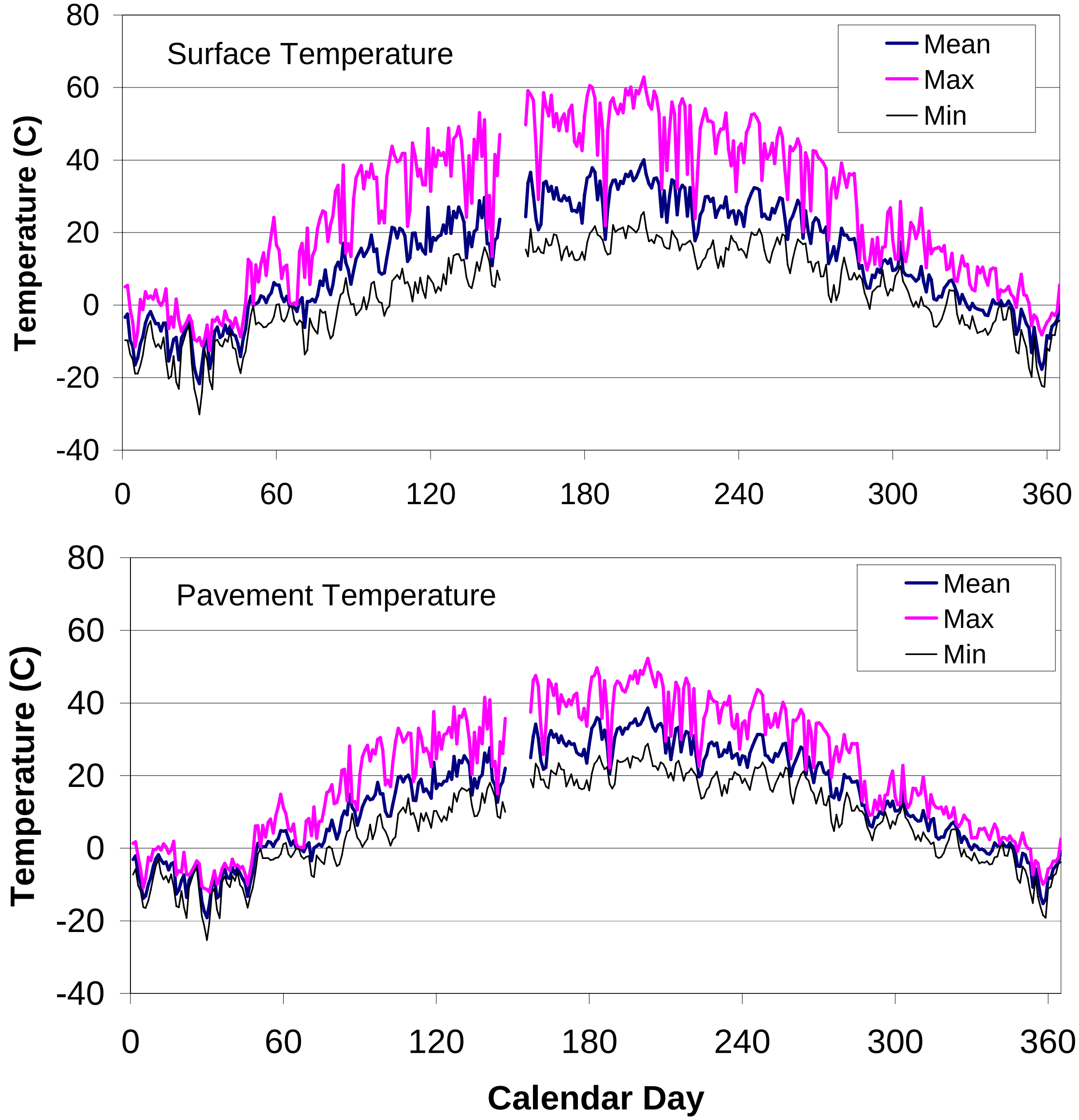
# Spectral Analysis of Asphalt Pavement Surface

- Significant more research needed - “pavement health” estimation is very complex
  - 40 different physical pavement properties listed in the pavement condition rating manual (ASTM D6433)
  - Some refer to visual characteristics
  - Others address subsurface conditions that spectral sensors do not see
    - ✓Ground penetrating equipment needed
- In the short term, remote sensing may offer some insight into subsurface conditions and other aspects usually detected through destructive testing

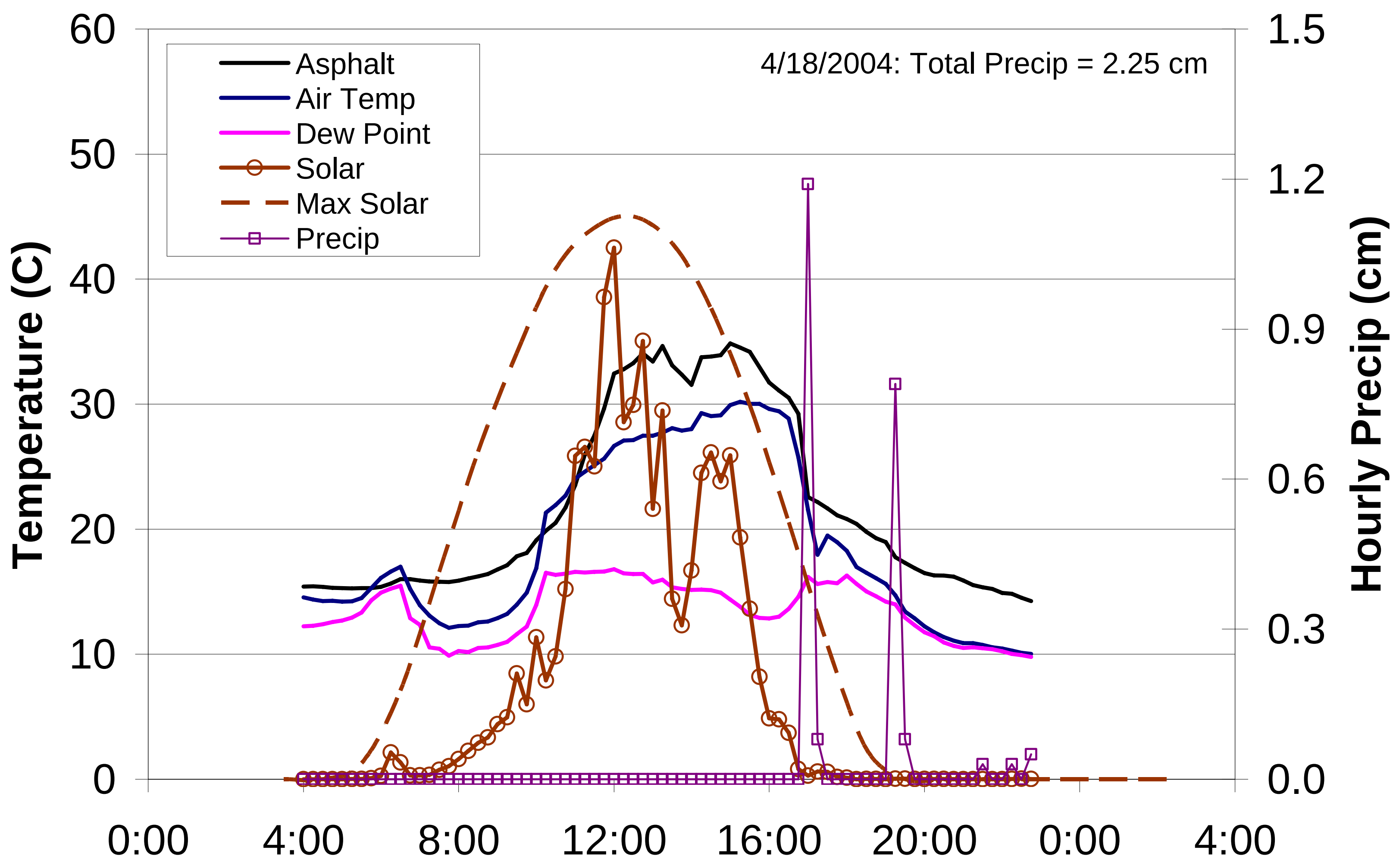
# Temperature Analysis

- Substantial analysis of measured pavement temperature data from the MnROAD facility
  - Measured pavement temperatures were characterized at diurnal and seasonal time scales, including daily extreme temperatures and temperature gradients, diurnal cycling, and seasonal variations
- Simulations of pavement temperature using a one-dimensional finite difference heat transfer model
  - Provided detailed information on temperature gradients in the pavement and on the surface heat transfer components

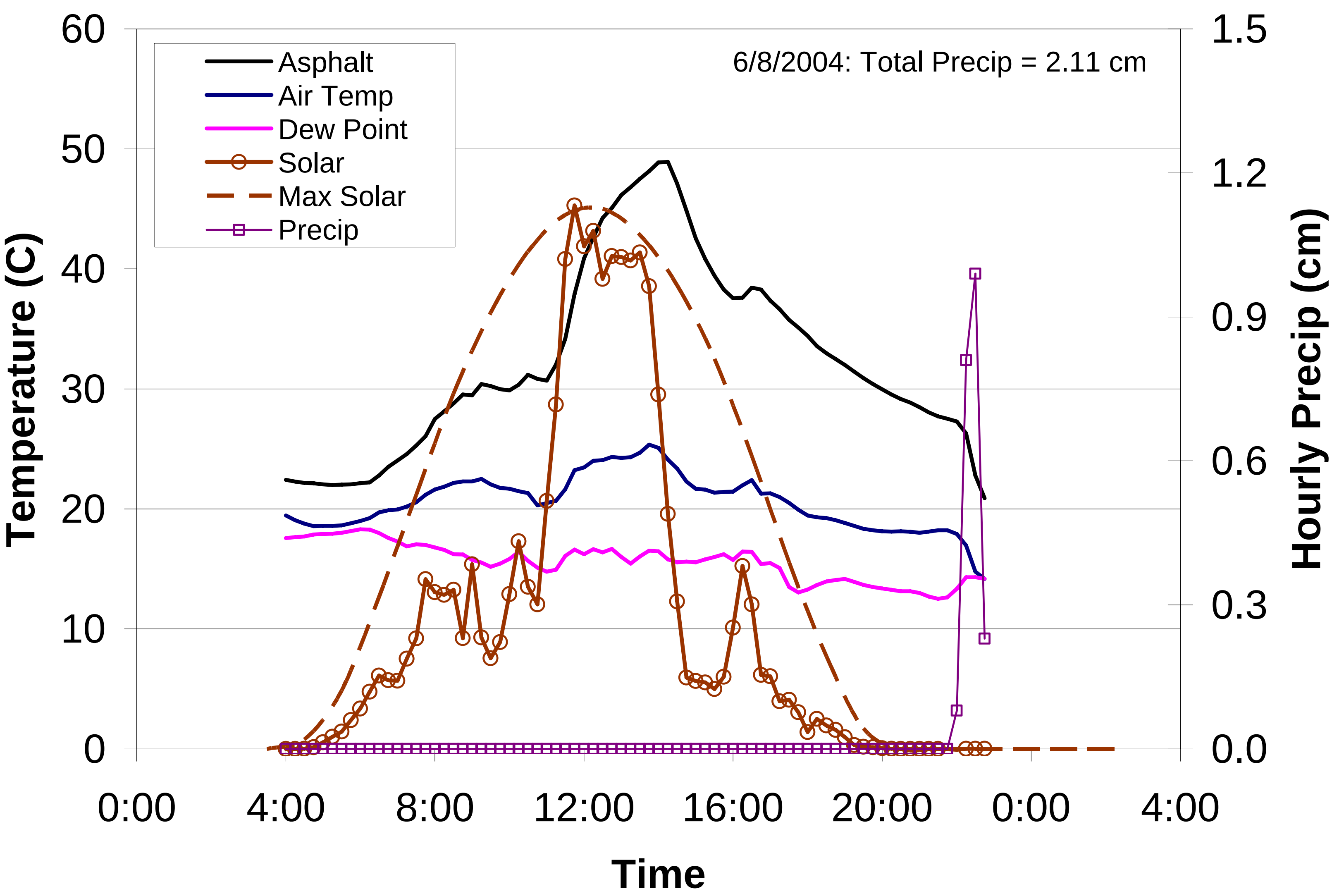
# Daily mean, maximum, and minimum surface and pavement temperature for test cell 33, 2004



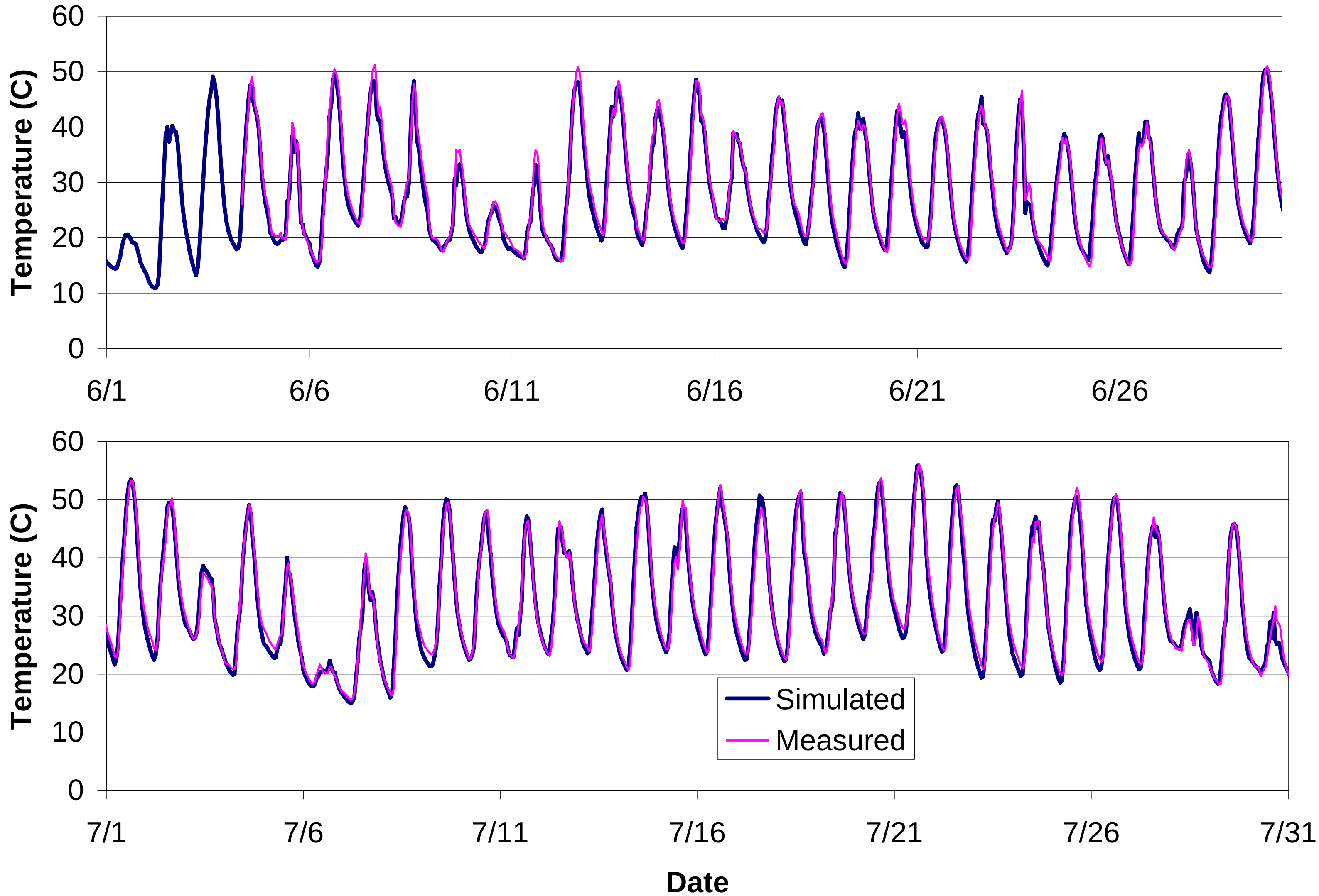
# High Cooling Event



# High Heating Event



# Simulated vs. Measured (Cell 33, 2.5cm depth)



# My "two cents"

- Define what aging is, what are the "markers" of aging, and specify how to detect them
- Investigate and quantify/model aging effect on mechanical properties over the entire spectrum of service temperatures
  - Fracture and fatigue resistance
  - Stiffness, modulus, phase angle, etc
- Investigate and quantify/model aging progress with time
  - **Need long term research**
- Propose and investigate methods to counteract aging and determine when is the best time to apply them

# Thank you!